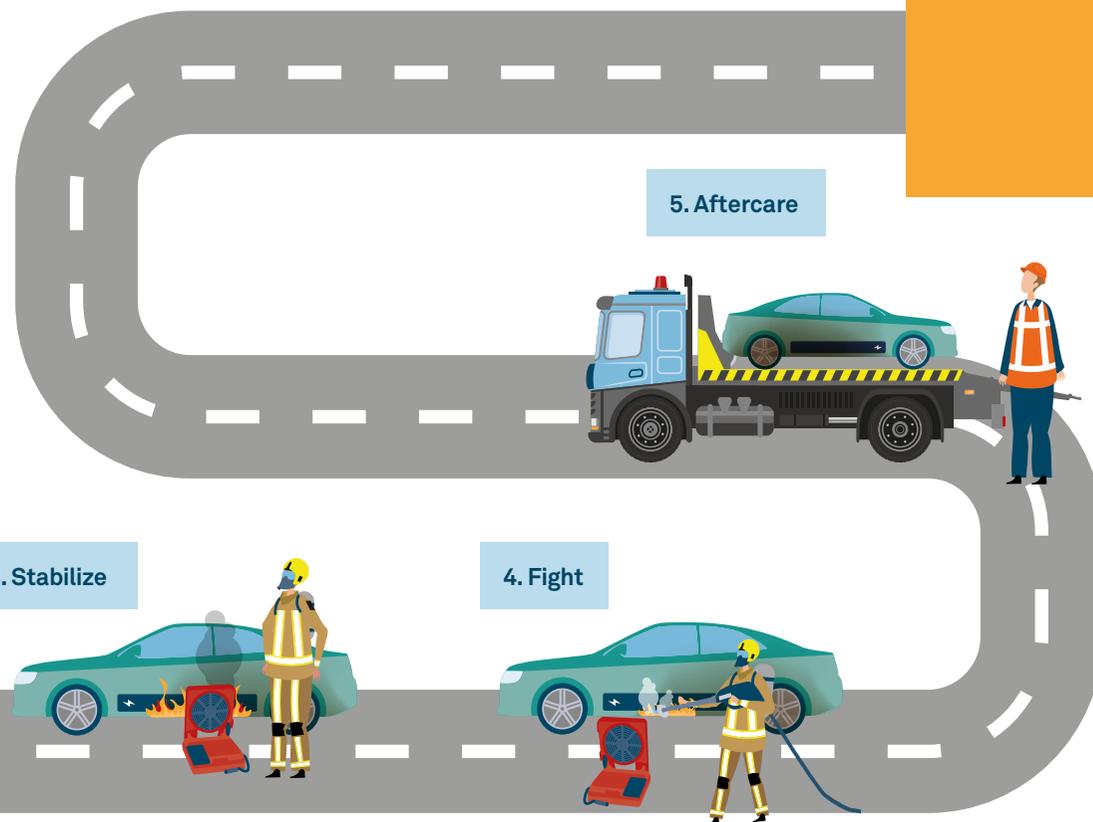


Recommendations for framework for action deploying UHP extinguishing system in case of fire in battery pack of electric vehicle

The conclusions of the fire experiments provide sufficient confidence to allow the fire department to deploy ultra high pressure cutting and extinguishing systems, provided that additional measures are taken compared to a standard UHP deployment.

The reasoning in this document stems from the premise that the vehicle fire, i.e. the fire in the bodywork, has already been extinguished.

Where numbering is applied, it is recommended to perform the steps in order of numbering. Where there is a > sign, no specific order is necessary.



1. Recognize

Identify the vehicle as an electrically powered vehicle. Determine if the battery is involved in the fire by use of the following indicators

- > Smoke: gray-white smoke or vapor from the battery pack.
- > Flames: flames or flares coming from openings around the battery pack.
- > Sound: a thermal runaway makes a popping, hissing and/or cracking sound due to the overpressure in the cells of the battery pack or the explosion of these cells.
- > Heat: the battery pack is hot (visible on a thermal imaging camera). Keep in mind that the thermal image may be disrupted by the smoke and the fact that battery cells are well-packed.

1. Recognize

2. Explore

3. Stabilize

4. Fight

5. Aftercare

Considering deployment techniques



2. Explore

Obtain assurance about the battery pack being involved in the fire.

1. Determine the location of the battery pack using the rescue information sheet.
2. Wear a breathing apparatus during the exploration.
3. If one of multiple of the aforementioned recognition indicators are present, there is a thermal runaway.
4. Observe from which side of the vehicle (most of) the gasses and flares escape. Approach the hot spot from the opposite side of the vehicle; the side of the vehicle from which no or less flares and gasses are escaping. Act upwind as much as possible in doing so.
5. Visually determine if there is a gas buildup in the vehicle, for example if all doors and windows are still closed. If this is the case, a safe work environment needs to be established first (see stabilize). Pay attention to possible gas buildups in the vicinity of the vehicle as well, for example under a carport.
6. If no gas buildup can take place, use a thermal imaging camera to look for hot spots at the battery's location. An example of a location to observe is the interior floor.

Once it has been established that the battery pack is involved:

- > Determine the largest hot spot using the thermal imaging camera. This will be the so-called penetration spot, on which the nozzle of the UHP system will be deployed.

- > Next, determine the closest suitable deployment position for the UHP operator. This is a position where the UHP operator can start the deployment without being exposed to flames or flares from the battery pack.
- > If there are flames at the closest suitable deployment position, find another suitable position.
- > If there is no suitable deployment position for the first-choice penetration spot, find an alternative hot spot (penetration spot) that can be reached without exposing the UHP operator to flames.

Consideration: Take pollution of the surface water into account as a criterium when considering deploying a UHP extinguishing system, as it can cause (part of) the aquatic fauna to die if the amount is not sufficiently diluted.

- > Do not deploy an UHP extinguishing system if the UHP firewater can flow to small pools of water (areas of maximum 30m x 30m) with little outflow. An example is the UHP firewater flowing directly into a puddle through the roadside, and the puddle having no flow because e.g. a ditch ends up on it.
- > Do not deploy an UHP extinguishing system if the UHP firewater can flow to drinking water extraction areas.

1. Recognize

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3. Stabilize

Create a stable and safe work environment prior to deploying the UHP extinguishing system through the following actions:

- > Prepare one low-pressure jet to shield the UHP personnel.
- > If flames emerge from the battery pack, prepare a second low-pressure jet to suppress the flames.
- > Position a fan so that the UHP system operator has a tailwind from the fan during the deployment.
- > If all doors and windows are still closed, it is not safe to open any doors from a close range due to the risk of explosion. This also applies to situations in which there are gas buildups in the vicinity of the vehicle, for example under a carport or in a garage box.
- > In this case, use the UHP extinguishing system to bust the windows on both sides of the vehicle and keep distance until most of the gases have escaped the vehicle. The spray from the UHP extinguishing system also helps here to provide ventilation in the vehicle. If necessary, a fan can be positioned prior to removing the windows for additional ventilation and can be turned on immediately after the windows have been broken.

1. Recognize

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4. Fight

If the situation is safe, carry out the following steps:

1. If the UHP unit has an extension, use the extension for deploying the UHP extinguishing system.
2. Place the UHP extinguishing system on the penetration spot found in 'explore'.
3. Steam formation from evaporating water is a good indicator that the extinguishing is working. If no steam formation occurs after about one minute, find another deployment location.
4. UHP deployment may take several minutes. Once steam formation has stopped and only water is coming out of the battery pack, propagation of the thermal runaway has stopped.
5. Next, look for remaining hot spots ($\geq 50^{\circ}\text{C}$) using a thermal imaging camera.
6. Deploy the UHP extinguishing system on any remaining hot spots.
7. Repeat this process until no more hot spots can be observed on the thermal imaging camera.
8. Monitor the vehicle with a thermal imaging camera for any temperature rises for 30 minutes. In doing so, monitor multiple times per minute.

Caution!

- > Compartmented batteries may require multiple deployments on different compartments, because the water cannot flow through the entire battery pack.
- > Damage to the battery pack may require more frequent deployments or may make deployments impossible.
- > If a vehicle is inclined, position the UHP extinguishing system on the higher side of the incline, as the water flows to the lowest point.

1. Recognize

2. Explore

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5. Aftercare

- > If a thermal imaging camera has not measured a temperature > 50°C for 30 minutes, hand over the incident to a third party (e.g. a salvager).
- > Position the vehicle at least 5 meters away from other vehicles OR store the vehicle in a dry immersion container, which can be filled in case the batteries reignite.
- > The deployed units need to initiate their 'work clean' procedure and have their PPE cleaned in accordance with regional agreements.

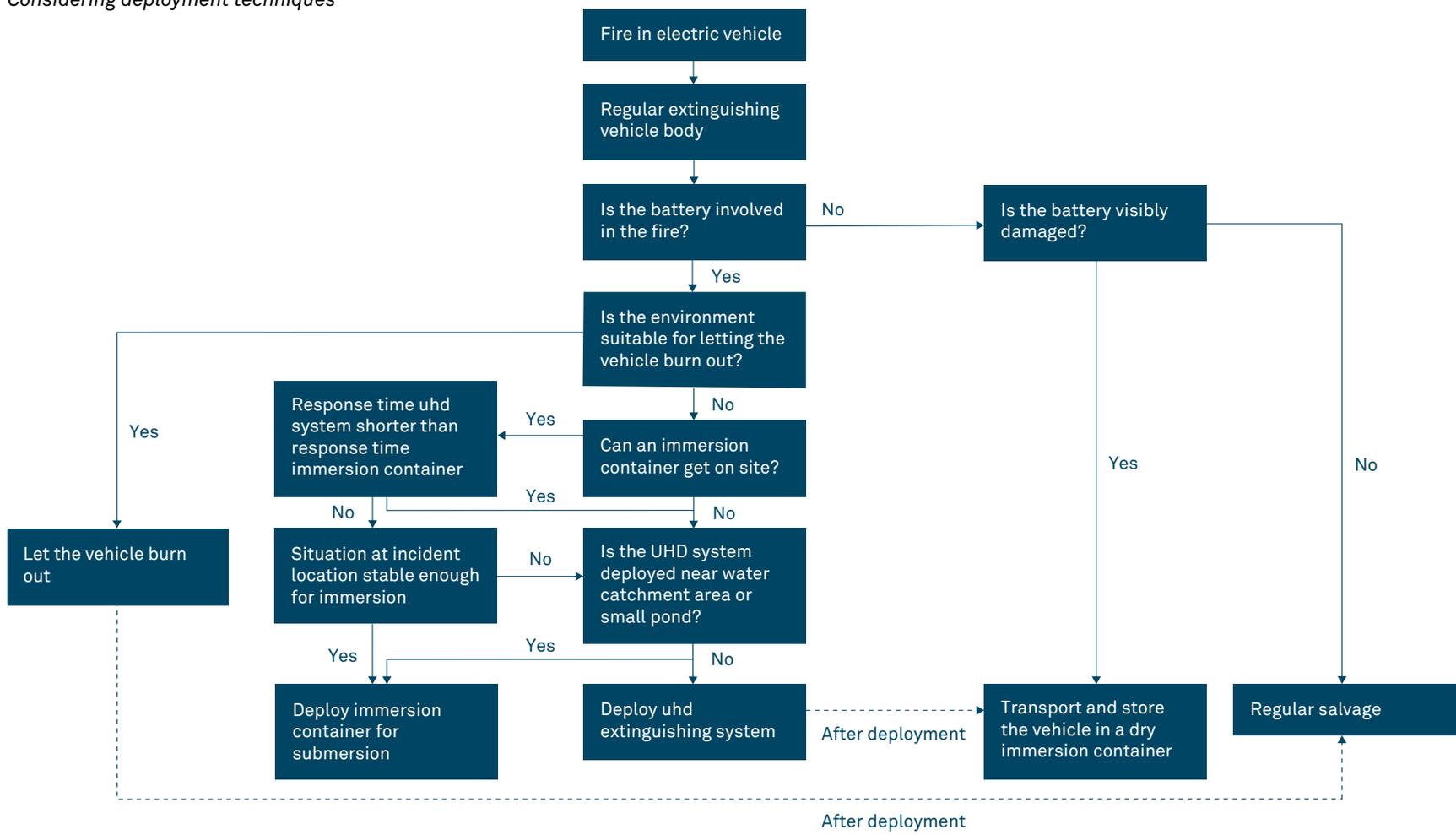
- 1. Recognize
- 2. Explore
- 3. Stabilize
- 4. Fight
- 5. Aftercare**
- Considering deployment techniques





Considering UHP extinguishing in relation to other deployment techniques

Considering deployment techniques



The flowchart provides no guidance for the situation where a vehicle cannot burn out in a controlled manner, there is no submersion container available, and the site is near a water catchment area. In this specific situation, the commanding officer must make an individual assessment.

- 1. Recognize
- 2. Explore
- 3. Stabilize
- 4. Fight
- 5. Aftercare
- Considering deployment techniques